

July 21, 1942.

J. E. HAINES

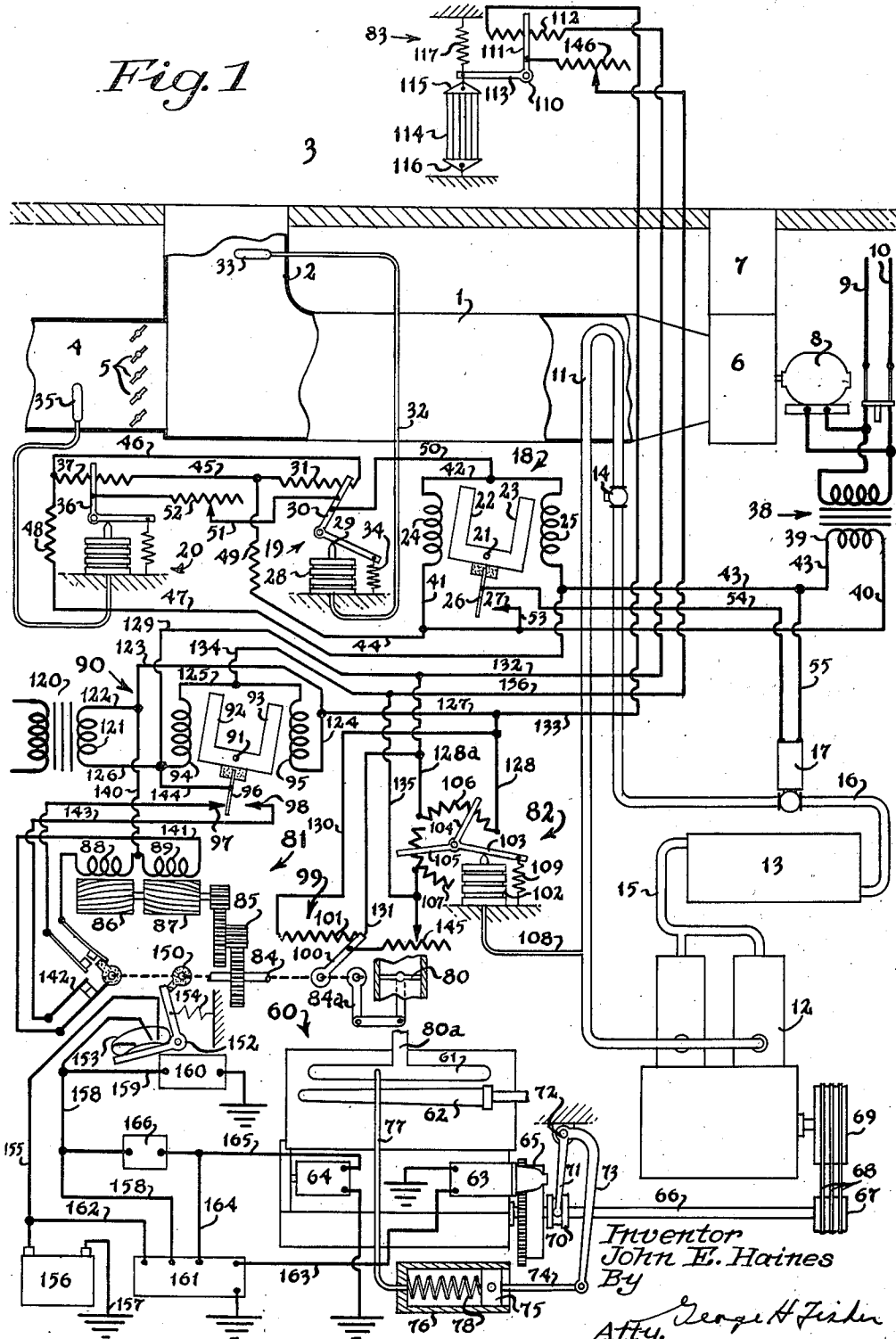
2,290,426

AIR CONDITIONING SYSTEM

Filed July 16, 1937

2 Sheets-Sheet 1

Fig. 1



July 21, 1942.

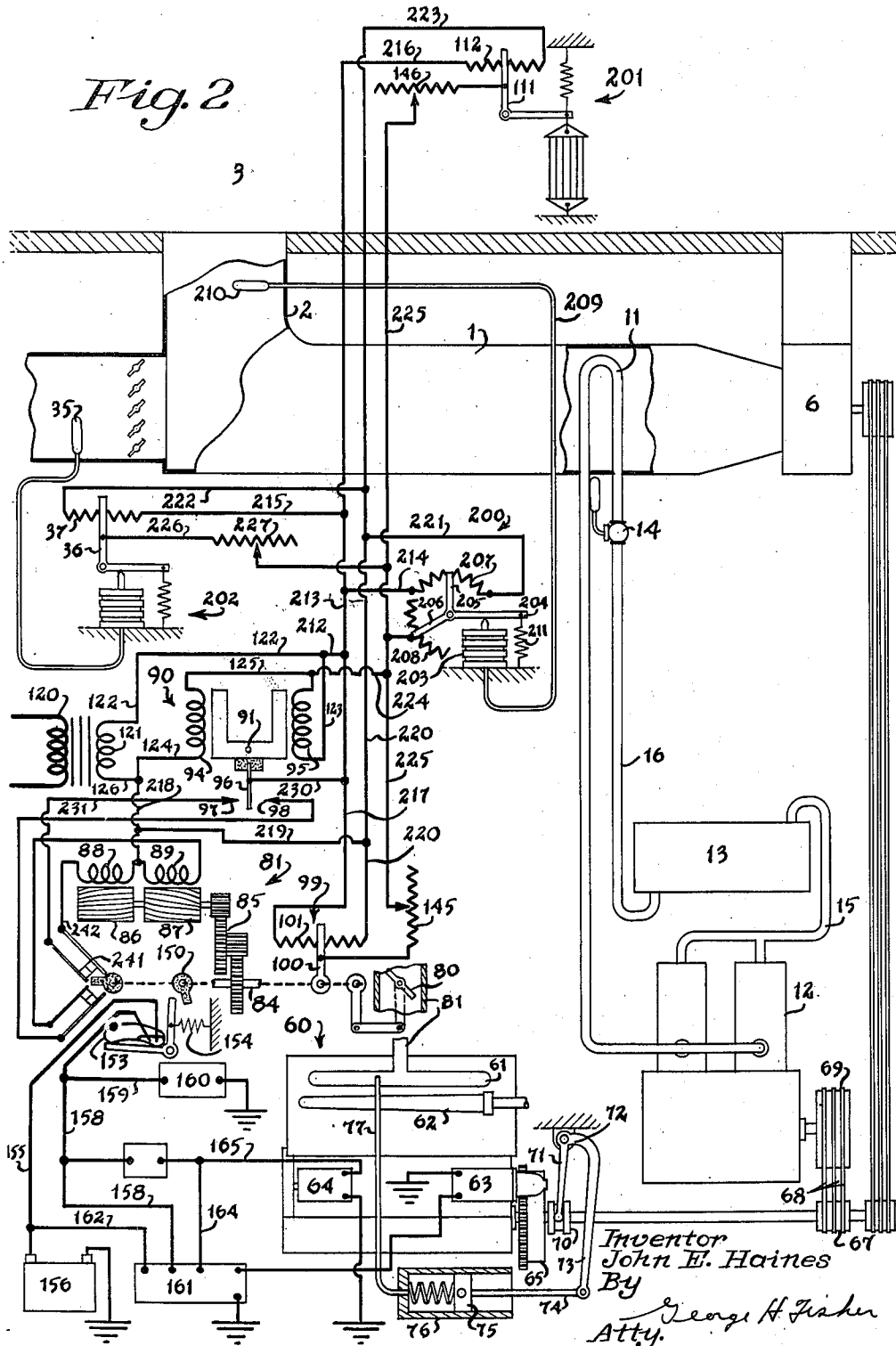
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UNITED STATES PATENT OFFICE

2,290,426

AIR CONDITIONING SYSTEM

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This invention relates generally to air conditioning systems and is more particularly concerned with air conditioning systems of the type utilizing a compression refrigeration system wherein the compressor is driven by means of an internal combustion engine.

The primary object of my invention is to provide a dependable control arrangement which is especially adapted for systems of this type, such control arrangement acting automatically to control the operation of the system in a manner to maintain proper temperature and humidity conditions within the conditioned space.

A more specific object of my invention is the provision of a novel air conditioning control system which automatically and gradually adjusts the speed or output of the internal combustion engine in accordance with the total requirements for refrigeration of the air conditioning system, and which simultaneously varies the action of the air conditioning system as between sensible heat cooling and dehumidification in a manner to maintain both the temperature and humidity conditions of the air within the space at desired values.

A further object of my invention is to provide a system which obtains the results above mentioned and which also acts automatically to start the internal combustion engine upon a demand for air conditioning; and which automatically places the engine out of operation when the demand for refrigeration ceases, or whenever such demand for refrigeration becomes so small as to require operation of the engine at too low an output.

While my invention is more concerned with air conditioning systems of the type utilizing internal combustion engine drive, certain features of the invention are applicable to air conditioning systems in general. Other and more specific objects of my invention will appear from the following detailed description and from the appended claims.

For a full disclosure of my invention, reference is made to the following detailed description and to the accompanying drawings, in which

Figure 1 is a diagrammatic illustration of an air conditioning system embodying one form of my invention; and in which

Figure 2 illustrates diagrammatically an air conditioning system having a modified control arrangement.

Referring to Figure 1, reference character 1 indicates generally an air conditioning chamber, this chamber having connected thereto a return

air inlet duct 2 which leads from a space to be conditioned 3, and to a fresh air inlet duct 4 which leads from outside the building. The fresh air inlet 4 is provided with suitable dampers 5 for controlling the admittance of fresh air into the conditioning chamber 1. The outlet of the conditioning chamber is connected to a fan 6, this fan, in turn, being connected to a discharge duct 7, which discharges conditioned air into space 3. Fan 6 is shown as being driven by an electric motor 8 which is connected through a suitable switch to line wires 9 and 10.

Located within the conditioning chamber 1 is a direct expansion cooling coil 11, this cooling coil forming a part of a compression refrigeration system, which includes a compressor 12, a condenser 13, and an expansion valve 14. The discharge of the compressor 12 is connected by a discharge conduit 15 to the inlet of the condenser, and the outlet of the condenser is connected to a liquid line 16 which leads to the expansion valve 14. The operation of compression refrigeration systems of this type is well known in the art and hence no detailed description of such operation is necessary. However, it may be stated that operation of the compressor 12 causes chilling of the cooling coil 11, and the temperature of the cooling coil 11 will vary in accordance with the compressor speed and also in accordance with the temperature of the air contacting said cooling coil.

Interposed in the liquid line 16 is a solenoid refrigerant valve 17 for stopping the flow of refrigerant into the cooling coil at times. The solenoid valve 17 may be of any suitable form and is herein illustrated as being of the type which opens when energized and which closes when deenergized. The solenoid valve 17 is controlled by a balancing type of relay generally indicated as 18 and this relay is, in turn, controlled by a return air temperature controller 19 and an outdoor temperature responsive thermostat 20.

The balancing relay 18 comprises a U-shaped armature which is pivoted at 21, this armature having legs 22 and 23 which cooperate with coils 24 and 25, respectively. The pivoted armature carries through a suitable insulating connection a switch arm 26 which cooperates with a contact 27. By this arrangement, energization of the coil 24 tends to cause clockwise rotation of the armature, this tending to cause switch arm 26 to disengage contact 27. The coil 25 on the other hand tends to cause a counter-clockwise rotation of the armature, thus tending to engage switch arm 26 with contact 27. It will be apparent that

so long as the coil 24 is energized more highly than coil 25, switch arm 26 will disengage contact 27, and that whenever coil 25 is energized more highly than coil 24, the switch arm 26 will engage contact 27.

The return air temperature controller 19 may be of any suitable form and as illustrated comprises a bellows 28 which is suitably fixed at its lower end and which cooperates with the actuating arm 29 of a bell-crank lever having a control arm 30, this control arm cooperating with a control resistance 31 to form a control potentiometer. The bellows 28 is connected by a capillary tube 32 to a control bulb 33 which is located in the return air duct 2. The bellows, tube and bulb contain a suitable volatile fluid whereby the vapor pressure within bellows 28 varies with the temperature surrounding the central bulb 33. Hence, as the return air temperature rises, the vapor pressure of the volatile fill will increase to cause an expansion of the bellows 28 which rotates the actuating arm 29 in a counter-clockwise direction against the action of a spring 34, this causing travel of the control arm 30 to the left across control resistance 31. Upon a decrease in return air temperature, the pressure within bellows 28 will decrease, this permitting movement of the control arm 30 to the right across resistance 31 under the action of spring 34.

The outdoor temperature responsive controller 20 may be formed in exactly the same manner as the controller 19, and in this case the control bulb 35 is located in the fresh air duct 4. The controller 20 is provided with a control arm 36 and a control resistance 37 which together form a control potentiometer.

Reference character 38 indicates a step-down transformer, the primary of which may be connected in parallel with the fan motor 8. The relay coils 24 and 25 are connected across the secondary 39 by wires 40, 41, 42, and 43. Also connected across the transformer secondary are the resistances 31 and 37 of the controllers 19 and 20, respectively. These resistances are connected across said transformer secondary by means of wires 44, 45, 46, 47, and 48, protective resistances 48 and 49 being interposed in the wires 47 and 44 for preventing excessive current from flowing when the control arms 30 or 36 reach an extreme position. Connected to wire 42 which joins the upper ends of relay coils 24 and 25 is a wire 50 which leads to the control arm 30 of the return air controller 19. The control arm 30 is also connected by a wire 51 to the control arm 36 of the controller 20, a rheostat 52 being interposed in said wire.

By the wiring arrangement just described, the control arm 30 divides the control resistance 31 into one portion which is in parallel with relay coil 24 and into another portion which is in parallel with the relay coil 25. For instance, the portion of resistance 31 to the left of the control arm 30 is connected in parallel with relay coil 24 as follows: left end of resistance 31, wire 45, wire 44, wire 41, relay coil 24, wire 42, and wire 50 to control arm 30. In a similar manner, the control arm 36 divides the resistance 37, the left half of said resistance being connected in parallel with relay coil 25 and the right half of said resistance being connected in parallel with relay coil 24. As the current flow through relay coils 24 and 25 will vary as the resistance in parallel with such coils is varied, it will be apparent that movement of either control arm 30 or control arm 36 will affect the relative energization of said relay coils.

The control arm 30 of controller 19 is shown as engaging the extreme right-hand end of control resistance 31, this causing the entire control resistance 31 to be connected in parallel with relay coil 24 while substantially short-circuiting the relay coil 25. Hence, more current will flow through relay coil 24 than through coil 25, this causing clockwise rotation of the armature to the position shown in which switch arm 26 is disengaged from contact 27. As the return air temperature increases, the control arm 30 will be shifted to the left across control resistance 31, thus decreasing the portion of resistance 31 which is in parallel with relay coil 24 and increasing the portion of said resistance which is in parallel with relay coil 25. This will cause the current flow in relay coil 24 to decrease and the current flow in relay coil 25 to increase. When the travel of control arm 30 to the left across control resistance 31 is sufficient to cause a greater current flow in relay coil 25 than occurs in relay coil 24, the switch arm 26 will engage contact 27, this opening the solenoid valve 17 by a circuit as follows: transformer secondary 39, wire 40, wire 53, contact 27, switch arm 26, wire 54, solenoid valve 17, wire 55 and wire 43 back to the transformer secondary. Therefore, when the space temperature increases to a predetermined value, the solenoid valve 17 will be opened, this permitting flow of refrigerant to the cooling coil 11.

It will be noted that the action of the controller 20 upon relay 18 is opposite to that of the return air temperature controller. In other words, upon an increase in outside air temperature, the controller 20 tends to cause the current flow in relay coil 25 to be decreased and that in relay coil 24 to be increased. Due to this effect, it will be apparent that the control arm 30 must move further to the left across resistance 31 in order to cause relay coil 25 to be energized more highly than relay coil 24, this requiring a higher return air temperature. The outside temperature responsive thermostat 20, therefore, acts, in effect, to adjust the temperature at which the return air temperature controller causes opening of the solenoid valve. It will be noted that rheostat 51 is interposed between the control arm 36 of the controller 20 and the relay 18. By adjusting this rheostat, the effect of controller 20 upon relay 18 may be varied. In this manner, the desired effect of the outside temperature controller upon the control point of the return air temperature controller 19 may be secured. This rheostat may be adjusted for instance so that for each 3° F. rise in outside temperature, the inside temperature maintained by controller 19 will be raised 1° F., thereby maintaining a variable differential between inside and outside temperature as ordinarily desired.

The compressor 12 is driven by means of an internal combustion engine 60, this engine being provided with the usual intake manifold 61, exhaust manifold 62, starting motor 63, generator 64 and fly-wheel 65. The fly-wheel 65 contains a suitable clutch mechanism as well known in the art and is connected to a drive shaft 66 carrying a pulley 67 over which run belts 68 for rotating pulley 69 which is mounted upon the compressor crank shaft.

In accordance with my invention, the internal combustion engine 60 is stopped and started automatically in accordance with load conditions. When this engine is automatically started, it is desirable that the compressor be disconnected therefrom and for this purpose a

suitable automatic mechanism for operating the clutch is provided. This mechanism is shown herein as comprising a clutch collar 70 which actuates the clutching mechanism, this collar cooperating with an arm 71 of a bell-crank lever 72 having an actuating arm 73 which is pivotally connected to a piston rod 74, this rod being attached to a piston 75 working in a suitable cylinder 76. The interior of the cylinder 76 is connected to the intake manifold 61 of the engine by a conduit 77. A spring 78 urges piston 75 outwardly, this causing the bell-crank lever 72 to be positioned for disengaging the clutching mechanism. When the engine is at rest, the pressure within the intake manifold 61 will be equal to atmospheric, this permitting the piston 75 to be moved by spring 78 for disengaging the clutch. When the engine 60 is started, however, a sub-atmospheric pressure will be developed within the intake manifold, this causing movement of piston 75 to the left for rotating bell-crank lever 72 in a direction for engaging the clutch. The clutching mechanism just described, therefore, acts automatically to unload the engine while it is being started and to connect the compressor thereto after the engine is started.

The speed of the engine 60 is controlled by means of a throttle valve 80 located in the fuel supply pipe 80a for the intake manifold. Throttle valve 80 is automatically positioned by means of a proportioning motor generally indicated as 81, this motor being controlled by means of a low-side or suction pressure controller 82 and by a space relative humidity controller 83.

Referring now to the proportioning motor 81, this motor may be of the type shown in Patent 2,028,110 issued to Daniel G. Taylor on January 14, 1936. Reference character 84 indicates an operating shaft having mounted thereon a lever arm 84a which is connected to the throttle valve 80 by suitable linkage. The operating shaft 84 is driven through a gear train 85 by a reversible electric motor means comprising armatures 86 and 87 which cooperate with field coils 88 and 89. It will be understood that armature 86 and field coil 88 form a motor for driving the shaft 84 in one direction while armature 87 and field coil 89 comprise a motor for driving the shaft 84 in the opposite direction.

The energization of the field coils 88 and 89 is controlled by means of a balancing relay 90, this relay comprising a U-shaped armature which is pivoted at 91 and having legs 92 and 93 which cooperate with relay coils 94 and 95, respectively. Armature 91 carries by a suitable insulating member a switch arm 96 which cooperates with contacts 97 and 98, respectively. When relay coils 94 and 95 are equally energized, the switch arm 96 will be disengaged from both contacts 97 and 98. If relay coil 94 becomes more highly energized than coil 95, the switch arm 96 will engage contact 97 as shown. When, however, relay coil 95 becomes more highly energized than coil 94, the switch arm 96 will engage contact 98. The relative energization of relay coils 94 and 95 is controlled by means of controllers 82 and 83 and also by means of a balancing potentiometer 99 which comprises a balancing arm 100 which is mounted upon the operating shaft 84, this balancing arm cooperating with a resistance 101.

The suction pressure controller 82 may be of any suitable form and is here shown as comprising a bellows 102 which is fixedly supported at

its lower end and which cooperates with the actuating arm 103 which actuates a control arm 104 and a corrector arm 105. The control arm 104 cooperates with a control resistance 106 to form a control potentiometer, and corrector arm 105 cooperates with a center tapped corrector resistance 107. The bellows 102 is connected to the suction line of the refrigeration system by a tube 108. When the suction or low-side pressure of the refrigeration system increases, the bellows 102 will expand against the action of a spring 109, this causing movement of arms 104 and 105 in a counter-clockwise direction across their respective resistances. Upon a decrease in suction pressure, the opposite action will take place, namely, the bellows 102 will contract thus permitting opposite rotation of arms 104 and 105 under the action of spring 109.

The space relative humidity controller 83 comprises a bell-crank lever 110 having a control arm 111 which cooperates with a resistance 112 to form a control potentiometer. The actuating arm 113 is connected to a humidity responsive device 114 which comprises a plurality of strands of hair or other moisture responsive material, these strands being secured by upper and lower clamping members 115 and 116, the upper clamping member 115 being secured to control arm 113 while the lower clamping member is fixedly supported. For urging the actuating arm 113 upwardly is a spring 117, this spring acting to maintain the strands taut. Upon a decrease in humidity, the strands will decrease in length, this causing rotation of the control arm 111 towards the left across resistance 112 against the action of spring 117. When the humidity increases, however, the strands will increase in length, this permitting the spring 117 to shift control arm 111 towards the right across resistance 112.

Reference character 120 indicates a step-down transformer, the primary of which may be connected to any suitable source of power. The relay coils 94 and 95 are serially connected across the secondary 121 by means of wires 122, 123, 124, 125, and 126. The control resistance 106 is also connected across the transformer secondary, the connections including wires 122, 123, 127, 128, 128a, 129 and 126. The balancing resistance 101 is connected in parallel with control resistance 106 across the transformer secondary by means of wires 130 and 131. The control resistance 112 of the humidity controller is also connected in parallel with the control resistance 106 by means of wires 132 and 133. To the wire 125 which joins the upper ends of relay coils 94 and 95 is attached a wire 134, this wire, in turn, being connected by a wire 135 connected to corrector resistance 107 and to the balancing arm 100 of the balancing potentiometer. The wire 134 is also connected to a wire 136 which leads to the control arm 111 of the humidity controller 83. By the wiring arrangement just described, it will be apparent that the control resistances 106 and 112, and the balancing resistance 101 are connected in parallel across the transformer secondary along with the relay coils 94 and 95 which are connected across such secondary in series. Also, it will be apparent that the upper ends of relay coils 94 and 95 are connected to each of the control arms and the balancing arm. This arrangement causes each of the control arms and the balancing arm to divide its respective resistance into one portion which is in parallel with relay coil 94 and into another portion which is in parallel with relay coil 95. Movement of

either of the control arms or the balancing arm across its resistance will therefore affect the current flow in relay coils 94 and 95.

With the parts in the position shown, the humidity is at an intermediate value as indicated by the control arm 111 engaging the center of resistance 112. The suction pressure is somewhat low as indicated by the control arm 104 assuming a position to the right of the center of control resistance 106. This will cause movement of the proportioning motor shaft 84 to fully close the throttle valve 80, the balancing arm 100 at this time engaging the extreme right end of balancing resistance 101. If the suction pressure should increase, the control arm 104 will be shifted to the left across resistance 106, this decreasing the portion of said resistance which is in parallel with relay coil 94 and increasing the portion of said resistance which is in parallel with relay coil 95. This will decrease the current flow through coil 94 and increase the flow through coil 95, which will result in switch arm 96 engaging contact 98. The engagement of switch arm 96 with contact 98 will energize the motor field 89 by a circuit as follows: transformer secondary 121, wire 122, wire 140, motor field 89, wire 141, limit switch 142, wire 143, contact 98, switch arm 96, wire 144 and wire 126 to secondary 121. Energization of motor field 89 will cause rotation of the shaft 84 in a counter-clockwise direction, thus moving the throttle valve 80 towards open position. At the same time, the balancing arm 100 will move to the left across balancing resistance 101, this reducing the portion of said resistance in parallel with relay coil 95 and increasing the portion of said resistance in parallel with relay coil 94. This will result in decreasing the current flow in relay coil 95 and increasing the current flow in relay coil 94, this tending to balance out the initial unbalancing effect of the relay of the controller 82. When the rotation of shaft 84 is such that the balancing potentiometer rebalances the current flows in relay coils 94 and 95, the switch arm 96 will disengage contact 98 thereby causing the motor to stop with the throttle valve in this new position. An increase in suction pressure will, therefore, cause the proportioning motor to move the throttle valve towards open position. It will be apparent that the movement of the proportioning motor 80 will be proportional to the movement of control arm 104 upon resistance 106, and hence the degree of opening of the throttle valve will be in proportion to the increase in suction pressure. Upon a fall in suction pressure, it will be apparent that the opposite action will take place, namely, the balancing relay 90 will be unbalanced in a direction to cause energization of motor field 88 for moving the throttle valve 80 towards closed position, this causing the balancing potentiometer to rebalance the relay for causing the throttle valve to be held in this further closed position.

It should be noted that interposed between the balancing arm 100 and the junction of the relay coils 94 and 95 is a rheostat 145. The purpose of this rheostat is to decrease the effect of the balancing potentiometer upon the energization of relay coils 94 and 95. This rheostat acts to diminish the flow of current through the balancing arm 100 and, therefore, requires a greater movement of balancing arm 100 on resistance 101 to cause a given variation in current flows through relay coils 94 and 95 than would occur if said rheostat were not present. By properly

adjusting this rheostat, the suction pressure controller 82 may be caused upon slight movement to cause such an unbalancing action on relay coils 94 and 95 as to require movement of the balancing arm through its entire range to rebalance. The action of the rheostat 145, therefore, is to increase the sensitivity of the suction pressure controller 82 thereby causing the operating range of such controller to be less than its total range. In other words, movement of control arm 104 over but a part of control resistance 106 will cause movement of the throttle valve from one extreme to the other.

Assuming the suction pressure remains constant, if the relative humidity increases, the control arm 111 will shift to the right across control resistance 112, this decreasing the portion of said resistance which is in parallel with relay 94 and increasing the portion of said resistance which is in parallel with relay coil 95. This will cause a decrease in current flow in relay coil 94 and an increase in current flow in relay coil 95, this acting to cause energization of motor field 89 for driving the throttle valve 80 towards open position. As the throttle valve is moved towards open position, the balancing potentiometer will gradually rebalance the relay 90 thus causing the deenergization of motor field 89 for stopping the motor with the throttle valve in a further open position. Conversely, upon a decrease in relative humidity, the opposite action will take place, namely, the proportioning motor will be energized to cause movement of the throttle valve 80 to a further closed position.

If the relative humidity increases, the humidity controller 83, in the manner described, will cause further opening of the throttle valve 80. This will result in increasing the engine speed and hence causing the suction pressure to decrease. This falling in suction pressure will act upon the controller 82 to cause it to slow down the engine. When the fall in suction pressure is such that controller 82 closes throttle valve 80 sufficiently to prevent further fall in pressure, the suction pressure will be maintained constant in this new value. An increase in relative humidity, therefore, acts, in effect, to cause adjustment of the suction pressure controller 82 to maintain a lower suction pressure within the refrigeration system. A decrease in relative humidity will have the opposite effect, namely, to cause the closing of the throttle valve thereby causing increase in suction pressure in the refrigeration system. It will be noted that interposed in the wire 136 which connects the control arm 111 of the humidity controller to the balancing relay is a rheostat 146. The purpose of this rheostat is to control the effect of the controller 83 upon the balancing relay 90 and to thereby determine the effect of controller 83 upon the control point of the suction pressure controller 82. By properly adjusting this rheostat, any desired change in suction pressure for a given change in humidity may be obtained.

In accordance with my invention, the speed of the engine is not only modulated but the engine is automatically stopped and started, the engine being stopped whenever the air conditioning load falls to a predetermined value and being automatically started whenever the load becomes sufficient to justify operation of the engine. This automatic starting and stopping mechanism will now be described. Mounted upon the operating shaft 84 of the proportioning motor is a switching member 150 which cooperates with an actu-

ating arm of a bell-crank lever 152 which is formed to carry a mercury switch 153. A spring 154 urges rotation of the bell-crank lever in a clockwise direction, thus biasing the mercury switch 153 to closed position. The switching member is so mounted upon the operating shaft 84 as to cause tilting of mercury switch 153 to open position whenever the throttle valve is moved to a predetermined minimum position. When the throttle valve is opened sufficiently to permit efficient operation of the engine, however, the switching member 150 will permit spring 154 to cause tilting of mercury switch 153 to closed position. One terminal of mercury switch 153 is connected by a wire 155 to a storage battery 156, one terminal of said storage battery being grounded as at 157. The other terminal of mercury switch 153 is connected to a wire 158, this wire being connected by a wire 159 to an ignition coil 160 for the engine. The wire 158 also leads to a starting relay 161. This starting relay may be of any suitable form, and if desired may be of the type shown and described in the Loehr et al. Patent No. 1,773,913, dated August 26, 1930. This type of starting relay is adapted to energize the starting motor whenever the control circuit of said relay is energized and for this purpose the starting relay 161 is connected to the storage battery and to the starting motor 63 by means of wires 162 and 163. This starting relay is also adapted to deenergize the starting motor when the engine starts and to prevent energization of the starting motor so long as the engine is in operation as evidenced by operation of the generator. For this purpose, the starting relay is connected to the generator 64 by means of wires 164 and 165. Reference character 166 indicates a suitable generator cutout. From the foregoing, it will be apparent that when mercury switch 153 closes, the ignition circuit for the engine will be closed, and simultaneously the starting motor will be placed into operation for causing starting of the engine. It also should be apparent that when the throttle valve 80 is closed to such an extent that mercury switch 153 opens, the ignition circuit for the engine will be broken, thereby causing the engine to stop.

It should be noted that mercury switch 153 is shown as being of the bent type having a wide differential of operation. This wide differential is necessary for preventing short-cycling of the control apparatus. While I have illustrated switch 153 as being of the mercury type, it will be understood that any switch type of wide differential switching mechanism may be employed.

Operation of Figure 1

With the parts in the position shown, the space or return air temperature is below the setting of the controller 19 as determined by the outside temperature controller 20. The relay 19 has, therefore, assumed a position in which switch arm 26 has disengaged contact 27, this causing closing of the solenoid valve 17. Due to no refrigerant passing into cooling coil 11, the suction pressure of the refrigeration system has decreased sufficiently to cause closing of the throttle valve, this also causing opening of the mercury switch 153 for placing the engine out of operation.

If now should the return air temperature rise above the control point of the return air temperature controller 19, the relay 18 will cause opening of solenoid valve 17. This will permit

flow of refrigerant into cooling coil 11. The refrigerant will evaporate in said cooling coil thereby causing the pressure within the cooling coil and suction line to increase. As the suction pressure increases, the controller 82 will cause movement of the proportioning motor in a direction to open the throttle valve 80. When the throttle valve 80 is opened sufficiently to permit proper operation of the engine, the mercury switch 153 will close, this causing starting of the engine in the manner just described. After the engine has started, the automatic clutching mechanism will engage to cause operation of the compressor 12. In this manner, when the temperature of the space being conditioned rises above the control point of controller 19, the system will automatically be placed into operation.

When the system is in operation, the speed of the compressor will be varied in accordance with both temperature and humidity conditions. Thus, if the temperature of the air being conditioned increases, a greater amount of refrigerant will be evaporated within cooling coil 11, this causing the suction pressure to increase. In response to this increase in suction pressure, the controller 82 will act to increase the engine speed. Similarly, upon a fall in the temperature of the air passing over the cooling coil, less refrigerant will be evaporated therein, this causing the suction pressure to decrease which, in turn, results in slowing down of the engine. The suction pressure controller 82 will therefore act to vary gradually the engine speed in a manner to carry the cooling load upon the system.

If the humidity increases, the humidity controller 83 will act to adjust controller 82 in a manner for maintaining a lower suction pressure. This will result in lowering the temperature of the cooling coil 11 which, in turn, will cause said cooling coil to condense more water vapor. An increase in humidity, therefore, acts to increase the dehumidifying effect of the cooling coil. Conversely, upon a decrease in humidity, the controller 83 will cause a higher coil temperature to be maintained, thus reducing the dehumidifying effect of the coil. In this manner, the humidifying effect of the cooling coil is varied in a manner to maintain the space relative humidity within predetermined limits.

From the foregoing it will be seen that the speed of the engine is varied in accordance with both the temperature and humidity conditions of the space being conditioned in a manner to maintain both the temperature and the humidity of the space being conditioned within predetermined values. It should also be apparent that whenever the temperature and humidity conditions are such that the load on the system is too light to justify operation of the engine, the control mechanism will automatically place the engine out of operation. It should further be apparent that if the temperature falls below the control point of controller 19, the refrigerant valve 17 will be closed, this stopping the flow of refrigerant into cooling coil 11 which, in turn, results in the suction pressure controller 82 operating to place the engine out of operation.

Figure 2

In Figure 2 the conditioning chamber, the refrigeration system, the automatic clutching mechanism and the automatic starting mechanism are identical to those illustrated in Figure 1, and hence these features are not described

here in detail. Corresponding parts in both figures are provided with the same reference characters.

In this figure, the throttle valve instead of being controlled in accordance with the suction pressure of the refrigeration system, is controlled conjointly by means of a return air temperature controller 200, a space relative humidity controller 201 and an outside temperature responsive controller 202. The humidity controller 201 and the outside temperature responsive controller 202 are formed similarly to the corresponding controllers illustrated in Figure 1, hence a detailed description of these controllers is unnecessary. The return air temperature controller 200 may be of any suitable form and is shown as comprising a bellows 203 which is fixedly secured at its lower end and which actuates an actuating arm 204 which carries a control arm 205 and a corrector arm 206, the control arm 205 cooperating with a resistance 207 to form a control potentiometer and the corrector arm 206 cooperating with a centered tapped corrector resistance 208. The bellows 203 is connected by means of a capillary tube 209 to a bulb 210 which is located in the return air duct 2. The bellows, tube and bulb contain a suitable volatile fill and hence upon an increase in return air temperature, the arms 205 and 206 will be rotated in a counter-clockwise direction across their respective resistances. Upon a decrease in return air temperature, these arms will be rotated in the opposite direction under the action of a spring 211.

As in the case of Figure 1, the throttle valve 80 is positioned by means of a proportioning motor 81, this proportioning motor being identical in construction to that illustrated in Figure 1 and including a relay 90. Relay 90 is identical in construction to the corresponding relay of Figure 1 and includes a pair of relay coils 94 and 95 cooperating with a pivoted U-shaped armature carrying a switch arm 96 adapted for engagement with contacts 97 and 98.

Reference character 120 indicates a suitable stepdown transformer having a secondary 121. As in Figure 1, the relay coils 94 and 95 are serially connected across the terminals of secondary 121 by means of wires 122, 123, 124, 125 and 126. Also connected to the wire 122 is a wire 212, this wire, in turn, being connected to wire 213 which is connected to the left-hand end of control resistance 207 by wire 214, to the right-hand end of resistance 37 of controller 202 by a wire 215, to the left-hand end of resistance 112 of the humidity controller 201 by a wire 216, and to the left-hand end of balancing resistance 101 by a wire 217. Also connected to the wire 126 leading from the transformer secondary 122 is a wire 218 which, in turn, is connected to wire 219 which is attached to a wire 220 which leads to the right-hand end of the balancing resistance 101. The wire 220 is also connected to the right-hand end of control resistance 207 by a wire 221, to the left-hand end of control resistance 37 by wire 222 and to the right-hand end of control resistance 112 by a wire 223. By the wiring arrangement just described, it will be apparent that each of the control resistances and the balancing resistance are connected in parallel across the terminals of the transformer along with the relay coils 94 and 95 which are connected across said transformer in series. A flow of current will, therefore, take place through the relay coils and through each of the resistances.

Attached to the wire 125 which joins the upper

ends of the relay coils 94 and 95 is a wire 224 which, in turn, is attached to a wire 225 which is connected at one end to the balancing arm 100 and at its other end to the control arm 111 of the humidity controller, rheostats 145 and 146 being interposed as shown. The wire 225 is also connected to the corrector resistance 208 as shown, and is connected to the control arm 36 of the outdoor temperature responsive controller 202 by means of a wire 226, a rheostat 227 being interposed in said wire. By this wiring arrangement, it will be noted that each of the control arms and the balancing arm is connected to the junction of relay coils 94 and 95. This has the effect of causing each of the control arms and the balancing arm to divide its respective resistance into one portion which is in parallel with relay coil 94 and another portion which is in parallel with relay coil 95. Movement of either of the control arms or the balancing arm, therefore, varies the resistance which is in parallel with relay coils 94 and 95, thereby varying the relative current flows in said relay coils.

With the parts in the position shown, each of the control arms is engaging the mid-portion of its respective resistance. For this position of the controllers, the proportioning motor has assumed the position in which the balancing arm engages the center of the balancing resistance, in this position the throttle valve 80 being half open. If now should return air temperature increase, the bellows 203 will expand, this causing movement of control arm 205 to the left across control resistance 207, this decreasing the portion of said resistance which is in parallel with relay coil 95 and increasing the portion of said resistance which is in parallel with relay coil 94. This will cause an increase in current flow in relay coil 94 and a decrease in current flow in relay coil 95, thus causing switch arm 96 to engage contact 97. Engagement of switch arm 96 with contact 97 will energize the motor field 88 by a circuit as follows: from transformer secondary 121, wire 122, wire 212, wire 213, wire 230, switch arm 96, contact 97, wire 231, limit switch 241, wire 242, motor field 88 and wire 218 to secondary 126. Energization of motor field 88 will cause rotation of shaft 84 in a clockwise direction, this causing movement of the throttle valve 80 towards open position. Simultaneously with the opening movement of the throttle valve, the balancing arm 100 will be shifted to the right along balancing resistance 101, this decreasing the portion of said resistance which is in parallel with relay coil 94 and increasing the portion of said resistance which is in parallel with relay coil 95. This will cause an increase in current flow in relay coil 94 and a decrease in current flow in relay coil 95, thereby tending to balance out the initial unbalancing action of the controller 200. When the throttle valve is opened to such an extent that the balancing potentiometer balances out the initial unbalancing action of controller 200, the relay coils 94 and 95 will again become equally energized, this causing disengagement of switch arm 96 from contact 97 to thereby stop the motor or throttle valve in this new position.

Upon a decrease in return air temperature, the opposite action will take place, namely, the controller 200 will cause the relay coil 95 to become more highly energized than relay coil 94, this, in turn, causing engagement of switch arm 96 with contact 98 which energizes the motor field 89 for causing movement of the throttle valve towards closed position. It will be apparent that

during the closing movement of the valve, the balancing potentiometer will tend to rebalance the relay, and eventually will cause stopping of the motor with the throttle valve in a further closed position. The controller 200, therefore, acts to cause opening of the throttle valve upon an increase in return air temperature and to cause closing of the throttle valve upon a decrease in return air temperature. Thus, if the return air temperature increases, more fuel will be supplied to the engine, this causing said engine to operate at a higher speed which causes the temperature of the cooling coil 11 to be reduced thereby increasing the cooling effect of the system to counteract the rise in temperature. Similarly, upon a fall in temperature, less fuel will be supplied to the engine thereby reducing the cooling effect of the system to prevent further fall in space temperature.

It will be noted that rheostat 145 is interposed between the balancing arm 100 and the junction of relay coils 94 and 95. This rheostat acts to desensitize the balancing potentiometer in a manner to increase the sensitivity of the return air temperature controller 200. Due to rheostat 145 decreasing the current flow through the balancing arm 100, it will be apparent that a larger movement of said arm across the resistance will be required in order to cause a given effect upon the coils 94 and 95 than would be necessary were said rheostat not present. Thus, a relatively small movement of the control arm 205 across the control resistance 207 may cause such an unbalancing effect upon the relay coils 94 and 95 that a movement of the control arm 100 along its complete range of travel is required for rebalancing. By properly adjusting the rheostat 145, a temperature change, for instance 2° F., of the return air may cause movement of the throttle valve from one extreme position to the other even though the total range of the return air temperature controller 200 may be as high as 8° or 10° F. In other words, the function of the rheostat 145 is to make the operating range of controller 200 less than its total range.

Assuming the return air temperature remains constant, if the space relative humidity should increase, the control arm 111 will be shifted to the left across control resistance 112, this causing an increase in current flow in relay coil 94 and a decrease in current flow in relay coil 95. This will result in switch arm 96 engaging contact 97 for energizing motor field 88, this causing rotation of shaft 84 in a direction to open the throttle valve 80. Simultaneously, with this opening movement the balancing potentiometer will tend to counteract the initial unbalancing action of the humidity controller. When the throttle valve 80 has been opened a degree corresponding to the movement of control arm 111 across resistance 112, the relay 90 will become rebalanced, thus causing the motor to stop with the valve in this further opened position. An increase in relative humidity, therefore, acts upon the proportioning motor 81 in a manner to cause opening of throttle valve 80. Upon a decrease in humidity, the opposite action will take place, namely, the throttle valve will be moved towards closed position.

It will be apparent that by this arrangement the humidity controller 201 will vary the temperature maintained by the controller 200. For instance, when the relative humidity increases, the engine speed will be increased as just de-

scribed. This will cause the cooling effect of the coil 11 to be increased which eventually will result in lowering the temperature within the conditioned space 3. In response to this lowering in temperature, the return air temperature controller will begin slowing down the engine speed and when the return air temperature has fallen to such a point that controller 200 has slowed down the engine sufficiently to prevent further fall in temperature, the space temperature will be held constant at this point. An increase in relative humidity, therefore, acts to cause a lower temperature to be maintained within the conditioned space. Upon falling relative humidity, the opposite action will take place, namely, the humidity controller 201 will cause slowing down of the engine which eventually will result in the space temperature increasing. In response to this increase in space temperature, the controller 200 will begin increasing the engine speed, and when the increase in temperature is such that controller 200 causes operation of the engine at a sufficient speed for preventing further increase, the space temperature will be held constant at this point.

From the foregoing, it will be apparent that the humidity controller acts to adjust the control point of the return air temperature controller 200. In other words, the humidity controller 201 acts to shift the location of the operating range of the controller 200 within its total range in a manner to cause a higher temperature to be maintained in the space as the humidity falls, and a lower temperature to be maintained as the humidity increases. It will be noted that rheostat 146 is interposed between the control arm 111 of the humidity controller and the junction of the relay coils 94 and 95. This rheostat permits the effect of controller 201 upon the energization of coils 94 and 95 to be varied, and thereby provides for adjusting the effect of the humidity controller 201 upon the control point of the return air temperature controller 200. By properly adjusting rheostat 146, the humidity controller may be made to vary the temperature maintained upon a variation in humidity which is just sufficient for compensating for the effect on human comfort of the change in humidity. The temperature controller 200 and the humidity controller 201, therefore, cooperate to maintain a constant "comfort" or effective temperature within the conditioned space.

Assuming the temperature and humidity remain constant, if the outside temperature should increase, the control arm 36 of the temperature controller 202 will be shifted to the left across resistance 37, this decreasing the portion of said resistance which is in parallel with relay coil 94 and increasing the portion of said resistance which is in parallel with relay coil 95. This will increase the current flow in coil 95 and decrease the current flow in coil 94, thereby causing engagement of switch arm 96 with contact 98 to energize motor field 89, this causing rotation of shaft 84 in a direction to close the throttle valve 80. An increase in outside temperature will, therefore, act to cause the throttle valve 80 to be moved towards closed position. This will cause slowing down of the engine and hence cause the cooling effect of the coil 11 to be reduced. Due to the increase in cooling load caused by the increase in outside temperature, and to the reduction in cooling effect of coil 11, the space temperature will begin to rise. In re-

sponse to this rise in temperature, the return air temperature controller 200 will begin causing the engine speed to be increased and when the space temperature has risen to such a point that the engine speed is increased just sufficiently to prevent further temperature increase, the space temperature will be held constant at this new value. An increase in outside temperature, therefore, acts upon the controller 200 in a manner to cause said controller to maintain an increased value of temperature within the conditioned space. The rheostat 227 which is interposed between the control arm 36 and the balancing relay 90 provides for adjustment of the effect of controller 202 upon the control point of the return air temperature controller 200. By properly adjusting this rheostat, any desired effect may be obtained. For instance, the return air temperature controller may be made to raise its control point 1° F. for each 3° F. rise in outside temperature.

From the foregoing, it should be apparent that the controllers 200, 201 and 202 conjointly control the position of the throttle valve 80 in a manner to maintain a constant effective temperature for any given value of outdoor temperature and that the effective temperature maintained within the conditioned space will be varied as the outdoor temperature varies. It will be apparent that the operation of the starting mechanism is the same as described in detail in connection with Figure 1. Therefore, whenever the three controllers cause the throttle valve to be closed to such an extent as to indicate that the engine is operating at too low a speed, the mercury switch 153 will open, thus placing the engine out of operation. Conversely, when the three controllers cause the throttle valve to be opened to such an extent as to indicate that satisfactory operation of the engine will result, the mercury switch 153 will be closed, this causing the engine to be placed into operation.

In this embodiment of the invention, a wide differential type of switch 153 as in Figure 1 is illustrated. It will be understood that any suitable form of switch and switch actuating mechanism may be employed, and if desired, in this embodiment, a switch having a small differential of operation will be utilized.

While I have shown and described two embodiments of my invention, it will be apparent that many changes which are within the scope of my invention will be obvious to those skilled in the art. I, therefore, desire to be limited only by the scope of the appended claims and the prior art.

I claim as my invention:

1. In an air conditioning system, in combination, an evaporator, means for passing air to be conditioned in heat exchange relationship with said evaporator and to a space to be conditioned, a compressor for supplying refrigerant to said evaporator and for reducing the pressure in said evaporator, a controller for varying the output of said compressor, control means responsive to a condition which is a measure of the temperature of said evaporator for actuating said controller for varying the compressor output in a manner to increase said output upon an increase in said evaporator temperature and to decrease said output upon a decrease in said evaporator temperature, valve means for controlling the flow of refrigerant into said evaporator, a temperature responsive device, and a humidity responsive device, one of said responsive devices being arranged to control said valve means, and the other

of said responsive devices being arranged to adjust said condition responsive means.

2. In an air conditioning system, in combination, an evaporator, means for passing air to be conditioned in heat exchange relationship with said evaporator and to a space to be conditioned, a compressor for supplying refrigerant to said evaporator and for reducing the pressure in said evaporator, a controller for varying the output of said compressor, means responsive to a condition which is a measure of the temperature of said evaporator for actuating said controller for varying the compressor output in a manner to increase said output upon an increase in said evaporator temperature and to decrease said output upon a decrease in said evaporator temperature, valve means for controlling the flow of refrigerant into said evaporator, means responsive to the humidity of the air in said space for adjusting said condition responsive means in a manner to cause decrease in evaporator temperature upon an increase in humidity within said space, and means responsive to the temperature of the air in said space for controlling said valve means.

3. In an air conditioning system, in combination, a heat exchange device through which air is adapted to be passed for a conditioning action, means for supplying heat exchange fluid to said heat exchange device including a compressor, an internal combustion engine for driving said compressor, a controller for varying the output of said internal combustion engine, space temperature responsive means for adjusting said controller to vary the engine output in accordance with space temperature to maintain said space temperature constant, means responsive to outside temperature for adjusting said space temperature responsive means, and means actuated when the engine output is reduced to a predetermined low value for placing said engine out of operation.

4. In an air conditioning system, in combination, a heat exchange device through which air is adapted to be passed for a conditioning action, means for supplying heat exchange fluid to said heat exchange device including a compressor, an internal combustion engine for driving said compressor, a controller for varying the output of said internal combustion engine, space temperature responsive means for adjusting said controller to vary the engine output in accordance with space temperature to maintain said space temperature constant, means responsive to humidity for adjusting said space temperature responsive means, and means actuated when the engine output is reduced to a predetermined low value for placing said engine out of operation.

5. In an air conditioning system, in combination, an evaporator in heat exchange relationship with air of a space to be conditioned, a compressor connected to said evaporator for supplying refrigerant thereto and for withdrawing refrigerant therefrom, an internal combustion engine for driving said compressor, a controller for varying the output of said engine and consequently varying the temperature of said evaporator, motor means for positioning said controller, space humidity responsive means for exerting a controlling influence on said motor means to cause the evaporator temperature to be varied in accordance with variations in humidity of the air in said space, said humidity responsive means being arranged to cause the evaporator temperature to be decreased in re-

sponse to an increase in space humidity, means indicative of a change in the load on said evaporator for also exerting a controlling influence on said motor means, and stopping and starting means for said internal combustion engine, said stopping and starting means being arranged to cause stopping of said engine when said controller is positioned to demand an engine output below a predetermined minimum value; and to cause starting of said engine when the controller is positioned to demand an engine output above a predetermined value.

6. In an air conditioning system, in combination, a heat exchange device through which air is adapted to be passed for a conditioning action, said heat exchange device being of constant effective heat exchange area, means for supplying heat exchange fluid to said heat exchange device including a compressing means, a controller for gradually controlling said compressing means, means responsive to space temperature, humidity, and outside temperature, and connections between said responsive means and said controller for gradually controlling said compressing means conjointly in accordance with variations in space temperature, humidity, and outside temperature.

7. In a refrigeration system, in combination, an evaporator, a compressor for supplying refrigerant to said evaporator and for withdrawing refrigerant therefrom, an internal combustion engine for driving said compressor, a throttle valve for controlling the speed of said internal combustion engine, control means influenced by the pressure in the evaporator for controlling said throttle valve in a manner to increase the output of the engine upon increase in said pressure, a valve for controlling the flow of refrigerant into said evaporator, a device influenced by the heat content of the space for controlling said valve in a manner to close said valve when said space does not require refrigeration while opening said valve when the space requires refrigeration, and a device actuated with said throttle valve for starting and stopping said engine.

8. In an air conditioning system, in combination, an evaporator over which air is passed for conditioning the air in a space, a variable capacity compressor connected to said evaporator for withdrawing refrigerant therefrom, said compressor having an output controller, means influenced by the pressure in the evaporator for controlling said output controller in a manner tending to maintain the evaporator pressure constant, a valve for controlling the flow of refrigerant into said evaporator, temperature responsive means responsive to space temperature, humidity responsive means responsive to space humidity, one of said responsive means adjusting said pressure influenced means and the other of said responsive means controlling said valve, and a device actuated by said output controller for placing said compressor out of operation when the output is reduced to a predetermined value.

9. In an air conditioning system, in combination, an evaporator over which air is passed for conditioning the air in a space, a variable capacity compressor connected to said evaporator for withdrawing refrigerant therefrom, said compressor having an output controller, means influenced by the pressure in the evaporator for controlling said output controller in a manner tending to maintain the evaporator pressure con-

stant, means responsive to the humidity in the space for adjusting said pressure influenced means for thereby varying the temperature of the evaporator in accordance with changes in humidity, a valve for controlling the flow of refrigerant into said evaporator, a thermostat responsive to the temperature in the space for controlling said valve, and a device actuated by said output controller for placing said compressor out of operation when the compressor output is reduced to a predetermined value.

10. In an air conditioning system, in combination, an evaporator, means for passing air to be conditioned in heat exchange relationship with said evaporator and to a space to be conditioned, a compressor for supplying refrigerant to said evaporator and for reducing the pressure in said evaporator, an internal combustion engine for driving said compressor, a controller for varying the output of said internal combustion engine, motor means for positioning said controller, control means responsive to a condition which is a measure of evaporator temperature for controlling said motor means, and means responsive to the humidity of the air for adjusting said control means for thereby varying the evaporator temperature in accordance with changes in humidity.

11. In an air conditioning system, in combination, an evaporator, means for passing air to be conditioned in heat exchange relationship with said evaporator and to a space to be conditioned, a compressor for supplying refrigerant to said evaporator and for reducing the pressure in said evaporator, an internal combustion engine for driving said compressor, a controller for varying the output of said internal combustion engine, motor means for positioning said controller, control means responsive to a condition which is a measure of evaporator temperature for controlling said motor means, means responsive to the humidity of the air for adjusting said control means for thereby varying the evaporator temperature in accordance with changes in humidity, and means actuated when the output of the internal combustion engine is reduced to a predetermined low value for placing said engine out of operation.

12. In an air conditioning system, in combination, a heat exchange device through which air is adapted to be passed for a conditioning action, means for supplying heat exchange fluid to said heat exchange device including a compressor, an internal combustion engine for driving said compressor, a controller for varying the output of said internal combustion engine, electrical means for starting said engine and for adjusting said controller, a control device including a movable member in control of said electrical means, space temperature responsive means for moving said movable member in a manner to control said electrical means to start said engine on a first rise in space temperature and to increase the engine output on further rise in space temperature to maintain said space at desired values, and means responsive to outside temperature for adjusting said space temperature responsive means.

13. In an air conditioning system, in combination, a cooling device through which air is adapted to be passed for a conditioning action, means for supplying cooling fluid to said cooling device comprising a compressor, an internal combustion engine for driving said compressor, a controller for varying the output of said internal

combustion engine, motor means for positioning said controller, control means responsive to a condition which is a measure of the temperature of said cooling device for controlling said motor means, and means responsive to the humidity of the air for adjusting said control means for thereby varying the action of said cooling device in accordance with changes in humidity.

14. In an air conditioning system, in combination, a cooling device through which air is adapted to be passed for a conditioning action, means for supplying cooling fluid to said cooling device comprising a compressor, an internal combustion engine for driving said compressor, a controller for varying the output of said internal combustion engine, motor means for positioning said controller, control means responsive to variations in the load on said cooling device for controlling said motor means, means responsive to the humidity of the air for adjusting said control means for thereby varying the action of said cooling device in accordance with changes in humidity, and means actuated when the output of the internal combustion engine is reduced to a predetermined low value for placing said engine out of operation.

15. In an air conditioning system, in combination, a cooling device through which air is adapted to be passed for a conditioning action, means for supplying cooling fluid to said cooling device comprising a compressor, an internal combustion engine for driving said compressor, a controller for varying the output of said internal combustion engine, motor means for positioning said controller, control means responsive to variations in the load on said cooling device for controlling said motor means, means responsive to the humidity of the air for adjusting said control means for thereby varying the action of said cooling device in accordance with changes in humidity, and means actuated when said controller is positioned to demand an engine output in excess of a predetermined low value for causing starting of the engine in the event that the engine is not in operation.

16. In an air conditioning system, in combination, a cooling device through which air is adapted to be passed for a conditioning action, means for supplying cooling fluid to said cooling device comprising a compressor, an internal combustion engine for driving said compressor, a controller for varying the output of said internal combustion engine, motor means for positioning said controller, control means responsive to variations in the load on said cooling device for controlling said motor means, means responsive to the humidity of the air for adjusting said control means for thereby varying the action of said cooling device in accordance with changes in humidity, and means actuated with said controller for stopping and starting said internal combustion engine, said last named means being arranged to stop the engine when the controller is positioned to demand an engine output below a predetermined low value and to start the engine when said controller is positioned to demand an engine output in excess of a predetermined low value.

17. In a refrigeration system, in combination, an evaporator for changing the heat content of a space, variable capacity compressor means connected to the evaporator, an output controller for varying the output of the compressor means, control means influenced by the pressure in the evaporator for controlling the output controller in a manner to increase the output of the compressor means upon increase in pressure, a first device influenced by a condition of the air in said space which is affected by the temperature of the evaporator for adjusting said control means to thereby vary the temperature of the evaporator upon change in said condition, valve means for controlling the flow of refrigerant into the evaporator, and a second device influenced by the heat content of said space for controlling said valve means.

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